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Renewable energy sources for clean and sustainable energy policies in Turkey

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ABSTRACT

Energy is an essential factor to achieve sustainable development. So, countries striving to this end are seeking to reassess their energy systems with a view towards planning energy programmes and strategies in line with sustainable development goals and objectives. As would be expected, the rapid expansion of energy production and consumption has brought with it a wide range of environmental issues at the local, regional and global levels. States have played a leading role in protecting the environment by reducing emissions of greenhouse gases. Turkey is an energy importing country with more than half of the energy requirement being supplied by imports, and air pollution is becoming a great environmental concern in the country. On the other hand, Turkey's geographical location has several advantages for extensive use of most of the renewable energy sources. In this regard, renewable energy resources appear the most efficient and effective solutions for clean and sustainable energy development in Turkey. This paper provides an overview of global energy use and renewables for clean and sustainable energy policies in Turkey.

Contents

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1. Introduction

Energy is essential to economic and social development and improved quality of life in all countries. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption in the country. Electricity supply infrastructures in many developing countries are being rapidly expanded as policymakers and investors around the world increasingly recognize electricity's pivotal role in improving living standards and sustaining economic growth [1].

Energy needs are continuously increasing and the demand for electrical power continues to grow rapidly. The world energy market has to date depended almost entirely on nonrenewable, but low cost, fossil fuels. Hydroelectric developments throughout the world provide approximately one-fifth of the world's total electrical energy. According to a study prepared for the Water and Sustainable Development International Conference in March 1998, even at a conservative estimate, the total exploitable hydro potential in the world amounts to at least six times as much [2].

Turkey is one of the largest countries in Europe and Middle East with its 779,452 km^2 total area (23,764 km^2 on the European side, 755,688 km^2 on the Asian side). The country lies between 36–42 north latitude and 26–45 east longitude (roughly rectangular in shape) and situated between two continents - Europe and Asia. It is surrounded by three seas with a total of 8372 km total coastline; the Aegean with 2805 km, the Mediterranean with 1577 km, the Black Sea with 1695 km and the inner sea Marmara with 972 km. The Marmara connects the Black Sea and the Aegean via two straits: Istanbul and Canakkale straits. The country has seven geographical regions: Marmara, Aegean, Mediterranean, Southeast Anatolia, East Anatolia, Black Sea and Central Anatolia. The neighboring countries are Greece and Bulgaria to the northwest, Armenia and Georgia to the northeast, Iraq and Iran to the southeast and Syria to the south. The highest mountain in Turkey is Mount Ararat (5165 m) and biggest lake is Lake Van: both are located in eastern Anatolia. On the other hand, Turkey is the fifteenth most populated country in the world with approximately 73 million inhabitants. Istanbul houses almost 15 million of these inhabitants, making the city one of the most populated cities in the world [3–7].

There is a growing concern that long-run sustainable development may be compromised unless measures are taken to achieve balance between economic, environmental and social outcomes. Since the early 1980s, Turkish energy policy has concentrated on market liberalization in an effort to stimulate investment in response to increasing internal energy demand. Turkey's new government has continued this policy despite lower energy demand induced by the 2001 economic crisis.

2. Global energy consumption

Global energy consumption in the last half century has rapidly increased and is expected to continue to grow over the future [8]. The past increase was stimulated by relatively "cheap" fossil fuels and increased rates of industrialization in North America, Europe and Japan; yet while energy consumption in these countries continues to increase, additional factors make the picture for the next five decades years more complex [9]. These additional complicating factors include China and India's rapid increase in energy use as they represent about a third of the world's population; the expected depletion of oil resources in the near future; and, the effect of human activities on global climate change [10]. On the positive side, the renewable energy technologies of wind, biofuels, solar thermal and photovoltaics are finally showing maturity and the ultimate promise of cost competitiveness [11–13].

Table 1
World primary energy demand by fuel (Mtoe).

	1980	2000	2006	2015
Coal	1788	2295	3053	4023
Oil	3107	3649	4029	4525
Gas	1235	2088	2407	2903
Nuclear	186	675	728	817
Hydropower	148	225	261	321
Biomass and waste	748	1045	1186	1375
Other renewables	12	55	66	158
Total	7223	10,034	11,730	14,121

The total primary energy demand in the world increased from 7223 million tons of oil equivalent (Mtoe) in 1980 to 11,730 Mtoe in 2006 (Table 1), representing an average annual increase of 2% [8]. However, it is important to note that the average worldwide growth from 2001 to 2006 was 4.1% with the increase from 2004 to 2008 being 4.3%. The rate of growth is rising mainly due to the very rapid growth in Pacific Asia which recorded an average increase from 2001 to 2006 of 8.6%. Fig. 1 shows world primary energy demand by fuel [8].

More specifically, China increased its primary energy consumption by 35% from 2000 to 2006 [8]. Unconfirmed data show similar increases continuing in China, followed by increases in India. Fuelled by high increases in China and India [8,9], worldwide energy consumption may continue to increase at rates between 3 and 5% for at least a few more years. However, such high rates of increase cannot continue for too long. Even at a 2% increase per year, the primary energy demand of 11 730 Mtoe in 2006 would double by 2050 and triple by 2070. With such high energy demand expected 50 years from now, it is important to look at all of the available strategies to fulfill the future demand, especially for electricity and transportation [8–10].

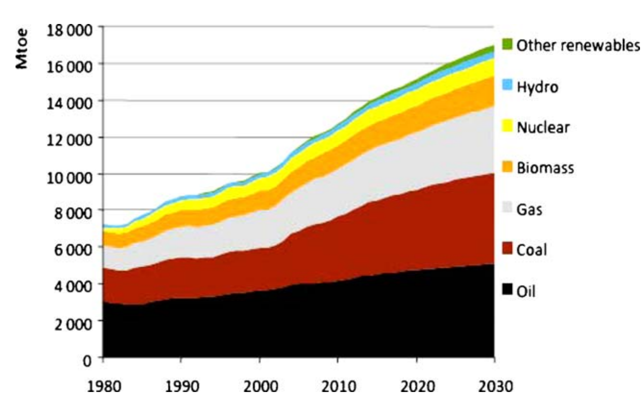

Fig. 1. World primary energy demand by fuel (Mtoe: million tons of oil equivalent).

3. Major sectors for primary energy use

The major sectors using primary energy sources include electrical power, transportation, heating, industrial and others, such as cooking. The International Energy agency (IEA) data shows that the electricity demand almost dubled from 1980 to 2006. This is not unexpected as electricity is a very convenient form of energy to transport and use. Although primary energy use in all sectors has increased, their relative shares have decreased, except for transportation and electricity. The relative share of primary energy for electricity production in the world increased from about 20% in 1980 to about 30% in 2006. This is because electricity is becoming the preferred form of energy for all applications [8,9].

Coal is presently the largest source of electricity in the world [8–10]. Consequently, the power sector accounted for 40% of all CO_2 emissions in 2006 [8]. Emissions could be reduced by increased use of renewables. All renewables combined accounted for only 17.7% share of electricity production in the world, with hydroelectric power providing almost 90% of it. However, as the renewable energy technologies mature and become even more cost competitive in the future they will be in a position to replace a major fraction of fossil fuels for electricity generation [11–13]. Therefore, substituting fossil fuels with renewable energy for electricity generation must be an important part of any strategy of reducing CO_2 emissions into the atmosphere and combating global climate change [14].

China will add the largest capacity with its projected electrical needs accounting for about 30% of the world energy forecasted. China and India combined will add about 40% of all the new capacity of the rest of the world. Therefore, what happens in these two countries will have important consequences on the worldwide energy and environmental situation. If coal provides as much as 70% of China's electricity in 2030, as forecasted by IEA [9], it will certainly increase worldwide CO_2 emissions which will further increase global warming.

At present, 95% of all energy for transportation comes from oil [9]. Therefore the available oil resources, their production rates and prices will greatly influence the future changes in transportation. Irrespective of the actual amount of oil remaining in the ground, oil production will peak soon. Therefore, the need is urgent for careful planning for an orderly transition away from oil as the primary transportation fuel. An obvious replacement for oil would be biofuels such as ethanol, methanol, biodiesel and biogases [8–11]. Some believe that hydrogen is another alternative, because if it could be produced economically from renewable energy sources or nuclear energy, it could provide a clean transportation alternative for the future. However, others think that electric transportation presents a more promising viable alternative to the oil-based transportation system [12,13].

4. World energy resources

4.1. Fossil fuels

With a view to meet the future demand of primary energy in 2050 and beyond, it is important to know the extent of available reserves of conventional energy resources including fossil fuels and uranium, and the limitations posed on them due to environmental considerations.on the other hand, if the British Petroleum (BP) estimated oil reserves are correct, world oil production may have already peaked [10]. If, however, estimates of the ultimate reserves are used, oil production may increase a little longer before it peaks. There is no question that once the world peak is reached and oil production begins to drop, either alternative fuels will have to be supplied to make up the difference between demand and supply, or the cost of fuel will increase precipitously and create an unprecedented social and economic crisis for our entire transportation system [8,9].

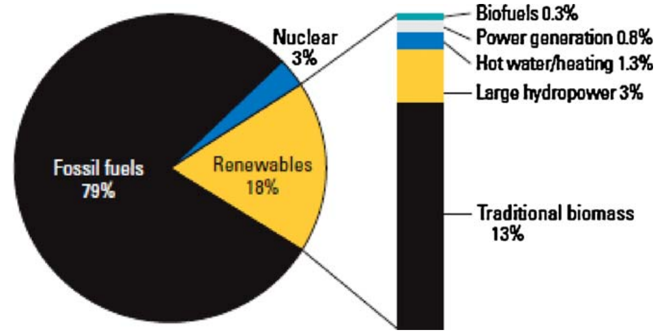

Fig. 2. Renewable energy share of global final energy consumption.

Coal is the largest fossil resource available to us and the most problematic from environmental concerns. From all indications, coal use will continue to grow for power production around the world because of expected increases in China, India, Australia and other countries. From an environmental point of view this would be unsustainable unless advanced "clean coal technology" (CCT) with carbon sequestration is deployed [12,13]. The CCT is based on an integrated gasification combined-cycle (IGCC) that converts coal to a gas that is used in a turbine to provide electricity with CO_2 and pollutant removal before the fuel is burned. However, no carbon capture and storage system is yet operating on a commercial scale. According to the estimates from the IEA [8,9], if the present shares of fossil fuels are maintained up to 2030 without any carbon sequestration, a cumulative amount of approximately 1000 gigatonnes of carbon will be released into the atmosphere [14]. This is especially troublesome in that the present total cumulative emissions of about 300 gigatonnes of carbon have already raised serious concerns about global climate change [9,14].

There are significant concerns about nuclear waste and other environmental impacts, the security of the fuel and the waste, and the possibility of their diversion for weapon production. At present, Uranium is the only fuel used for nuclear power and its terrestrial deposits are limited. Based on the known reserves of uranium, it is unlikely that nuclear power will be able to provide a significant part of our future energy. On the other hand, thorium could also be used for nuclear fission; however, to date nobody has developed a commercial nuclear power plant based on thorium. Although, these resources are potentially large, their cost effective recovery is highly questionable [13].

4.2. Renewables

Renewables accounted for 18% of the world's total primary energy supply in 2007 (Fig. 2). However, almost 80% of the renewable energy supply was from biomass, and in developing countries it is mostly converted by traditional open combustion which is very inefficient. Because of its inefficient use, biomass resources presently supply only about 20% of what they could if converted by modern, more efficient, available technologies. The total share of all renewables for electricity production in 2007 was about 17.6%, a vast majority (90.3%) of it being from hydroelectric power [11–13].

Wind technology has progressed significantly over the last two decades, driving down capital costs to as low as $900 per kW. At this level of capital costs, wind power is already economical at locations with fairly good wind resources. Therefore, the average annual growth in worldwide wind energy capacity increased from 8 to 94 GW for the last ten years. The total global installed power capacity reached a level of 94 GW in 2007 [15]. The world's total

theoretical potential for on-shore wind power is around 55 TW with a practical potential of at least 2.0 TW. The off-shore wind energy potential is even larger [1,2,11].

The amount of sunlight striking the earth's atmosphere continuously is 1.75×10^5 TW. Considering a 60% transmittance through the atmospheric cloud cover, 1.05×10^5 TW reaches the earth's surface continuously. If the irradiance on only 1% of the earth's surface could be converted into electric energy with a 10% efficiency, it would provide a resource base of 10^5 TW, while the total global energy needs for 2050 are projected to be about 25–30 TW [13]. The present state of solar energy technologies is such that single solar cell efficiencies have reached over 20% with concentrating PV at about 40% and solar thermal systems provide efficiencies of 40–60% [8–11].

The worldwide growth in PV production has averaged more than 50% per year during the past ten years. Solar thermal power using concentrating solar collectors was the first solar technology which demonstrated its grid power potential [11]. Progress in solar thermal power stalled after that time because of poor policy and lack of R&D. However, the last 5 years have seen a resurgence of interest in this area and a number of solar thermal power plants around the world are under construction. The cost of power from these plants has the potential to go down to $0.05/kW h with scale-up and creation of a mass market. An advantage of solar thermal power is that thermal energy can be stored efficiently and fuels such as natural gas or biogas may be used as back-up to ensure continuous operation [13].

Although theoretically harvestable biomass energy potential is of the order of 90 TW, the technical potential on a sustainable basis is of the order of 8–13 TW/yr [9,11]. This potential is 3–4 times the present electrical generation capacity of the world. The biggest advantage of biomass as an energy resource is its relatively straightforward transformation into transportation fuels. Biofuels have the potential to replace as much as 75% of the petroleum fuels in use for transportation in the USA today without the need for additional infrastructure development. Biofuels, along with other transportation options such as electric vehicles and hydrogen, will help diversify the fuel base for future transportation. Between 2000 and 2005 global ethanol production more than doubled to 36 billion litres [11,16,17].

5. Energy utilization in Turkey

As a developing country an in conjunction with its fast growing economy and population Turkey's energy consumption has increased rapidly between 1996 and 2008. While total primary energy consumption in 1996 was 70,776 kilo tons of oil equivalent (ktoe), in 2008 it raised 106,338 ktoe. On the other hand, total energy production in 1996 was 28,293 and 29,263 ktoe in 2008 (Table 2). The industrial sector accounted for 36% of total energy consumption, while residential and commercial sectors represented 33% in 2008. In recent years, the difference between the industrial and residential sectors has increased much more than in former years, according to the MENR (Ministry of Energy and Natural Resources) statistics [7,18].

As it can be seen in Fig. 3, Turkey is an energy importing country and dependent on the imported energy sources. Furthermore this trend seems to be continuing in the future. Although it has a wide variety of energy sources, the quality and quantity of most of the sources are not sufficient to produce energy. Some of the energy sources in Turkey are hard coal, lignite, asphalt, oil, natural gas, hydropower, geothermal, wood, animal & plant wastes, solar and wind energy [7,18]. The proven reserves of lignite, the most abundant domestic energy source, is 7300 million tons and found in almost all of the country's regions. Lignite has the largest percentage in total energy production with its 42.5% share. After lignite, wood has the greatest share in total energy production with its 20% and oil accounts for 13%, 12.4% hydro and the final 15% includes animal wastes, solar, hard coal, natural gas, geothermal electricity and geothermal heat [18–21].

Table 2
Energy production and consumption of Turkey in 2008 (ktoe).

Energy source	Production	Consumption
Hard coal	1204	14,179
Lignite	15,205	15,000
Asphaltite	265	265
Oil	2268	31,784
Natural gas	931	33 807
Hydropower	2861	2861
Geothermal-electricity	140	140
Geothermal-heat	1011	1011
Animal & plant wastes	1134	1134
Wood	3679	3679
Wind	73	73
Solar	420	420
Total	29,257	106,338

The MENR carries out the general energy planning studies, using an 'MAED' demand model, and TEIAS, (Turkish Electricity Transmission Company) carries out energy generation expansion planning studies, using the DECADES model [21]. The MAED model makes projections of the medium and long-term general electricity demand [22]. It takes into consideration a detailed analysis of social, economic and technical systems. The model is based on low, medium and high case scenarios. It is very important to project the energy demand accurately, because decisions involving huge investments of capital are based on these forecasts [18–22].

The Turkish Electricity Transmission Corporation (TEIAS), has prepared the Long-Term Energy Generation Plan, taking into consideration the MAED model demand outcome. According to the Plan, the installed capacity will increase to 57,551 MW in 2010 and to 117,240 MW in 2020. The installed hydropower capacity is anticipated to increase to 18,943 MW in 2010 and to 34,092 MW in 2020. Thus, an additional 1000 MW of hydro capacity should be added to the system annually over the next 20 years. Turkey is thus seeking support for the development of all its economic potential by 2023, which is the 100th anniversary of the foundation of the Turkish Republic [18–22].

In recent years, most significant developments in production are observed in hydropower, geothermal, solar energy and coal production. Turkey's use of hydropower, geothermal and solar thermal energy has increased since 1990. However, the total share of renewable energy sources in total final energy consumption (TFEC) has declined, owing to the declining use of non-commercial biomass and the growing role of natural gas in the system [18–22].

Turkey has recently announced that it will reopen its nuclear programme in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports. Turkey

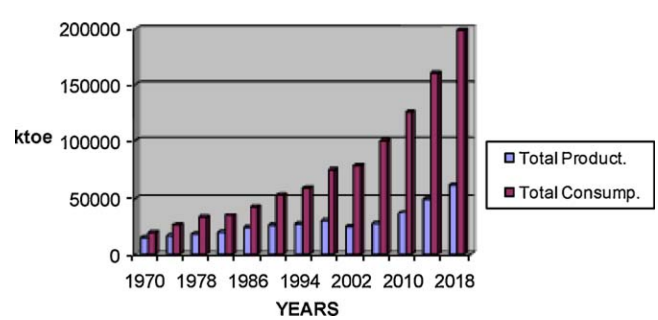

Fig. 3. Total energy production and consumption in Turkey.

does not currently have any nuclear power plants in operation or under construction, but has a long-standing nuclear research programme and has been considering nuclear power for many years. The 2009 Electricity Market and Security of Supply Strategy envisages a contribution from nuclear power by 2020. A number of steps have been taken over recent years to prepare the legal and institutional framework needed for a nuclear programme. A competitive tendering process for the construction of up to 5000 MW_e of nuclear capacity was launched in early 2008. However, only one bid was received. Following legal challenges to the process, in November 2009 it was announced that the tender had been cancelled. Direct negotiations have been continuing with potential suppliers, and in May 2010 an agreement was signed with the Russian Federation to build the country's first nuclear power plant [7,18].

Along with the economic growth and population increase, significant increases were observed both in primary energy and electricity consumption during the Ninth Development Plan period (2007–2013) [19]. Consumption of primary energy reached 119,641 ktoe as of the end of 2013 with an annual average increase of 2.9% while electricity consumption reached 219.3 billion kW h with an annual average increase of 4.6%. These increases are more evident in the period following 2003, since the impact of the 2001 economic crisis was alleviated, and the economy stabilized. During this term, primary energy and electricity utilization grew at an annual average rate of 5.7% and 6.7%, respectively [18,21].

The Total Final Energy Consumption (TFEC) in Turkey grew by 3.6% per year between 1990 and 2008. Coal and lignite are the domestic fuels, accounting for 27.5% of TEC in 2008. Oil (29.8%) and gas (31.8%) also contributed significantly. Renewable energy, mostly biomass, waste and hydropower, accounted for 8.8%. Hydropower represented 2.7% of TFEC in 2008. Biomass (wood & waste), primarily fuel wood consumed by households, represented almost 4.5% (Table 2). The economic downturn in Turkey in 2000–2008 caused TFEC to decline by 6.0%. But energy demand is expected to more than double by 2020, according to Turkish government sources. Hydropower is the main indigenous source for electricity production and represented 20–30% of total generation from 1970 to 2008 [18,21].

6. Renewable energy in Turkey

Renewable energy supply in Turkey is dominated by hydropower and biomass [18–25], but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. Total renewable energy supply declined from 1990 to 2007, due to a decrease in biomass supply [25]. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources. Table 3 shows potentials for investment for renewable energies in Turkey [9,18,23,26].

Table 3
Potentials for investment for renewable energies in Turkey.

Sectors	Million €	Remarks
Hydroelectric	114	Economical development potential of 28,600 MW, Corresponding 100,000 GW h/a
Wind power	57	Economical development potential of 48,000 MW With wind speed >7 m/s
Solar thermal	165	Economical development potential of 131,000 GWh/a Corresponding to approx. 300 million m^2 collector area
Biogas	4	Agricultural residual material and dung, when used for Electricity generation, 1000 MW_e and 7000 GWh/a
Total	340	

6.1. Hydropower

Hydropower is a renewable form of energy since it uses the power of flowing water, without vested or depleting it in the generation of energy. Because they are clean energy generation plants hydropower can contribute to reducing air pollution and slowing down global warming. Any other air pollutants or toxic wastes are not produced and it promotes energy safety independence and price stability. Hydropower is an electricity sources with long viability and low operation and maintenance cost [26–30].

Turkey's theoretical hydroelectric potential is 1% of that of the World and 16% of Europe. The gross theoretical viable hydroelectric potential in Turkey is 433 billion kW h and the technically viable potential is 216 billion kW h [28]. The economically viable potential, however, is 140 billion kW h. Annual energy consumption per capita in Turkey has reached 2900 kW h which is above world average of 2500 kW h. Annual increase in energy consumption is 8–10% in Turkey except for the recession years [7,18,26].

Currently, Turkey has 172 hydroelectric power plants in operation with total installed capacity of 13,700 MW generating an average of 48,000 GW h/year, which is 35% of the economically viable hydroelectric potential [30]. 148 hydroelectric power plants are under construction 8600 MW of installed capacity to generate average annual 20,000 GWh representing 14% of the economically viable potential. In the future, 1418 more hydroelectric power plants will be constructed in order to make use of additional 22,700 MW installed capacity. As a result of these works, a total of 1738 hydroelectric power plants with 45,000 MW will tame rivers to harness the economically viable hydropower of Turkey (Table 4).

Total energy generation in Turkey in the 1950s was 800 GW h, this figure has increased by about 256 times, reaching 191,555 GW h/year today. As of 2008, the current installed capacity is 42,359 MW, which could generate an average of 246,974 GW h/year. Capacity utilization has been 87% in thermal plants and 70% in hydroelectric power plants. 19% of energy generation depends on hydroelectric power and the remaining 81% on thermal power. A special emphasis has recently been placed on alternative energy sources such as wind and geothermal power. The share of geothermal and wind power in total energy generation has reached 2%. There have been some steps taken towards introducing the use of nuclear power as well. Table 5 shows renewable energy production in Turkey [7,18,23].

The national development plan aims to harvest all of the hydroelectric potential by 2020. The contribution of small hydroelectric plants to total electricity generation is estimated to be 5–10% [29,30]. The Southeastern Anatolia Project (GAP) is one of the largest power generating, irrigation, and development projects of its kind in the world, covering 3.0 million ha of agricultural land [32]. This is over 10% of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated are in Turkey. The GAP project on the Euphrates and Tigris Rivers encompasses 22 dams and 19 hydro plants. Once completed, 27 billion kW h of electricity will be generated and irrigating 1.7 million hectares [32].

The important river basins with an annual hydropower potential of more than 5 TW h are: Fırat (38,070 GW h), Dicle (16,702 GW h), Dogu Karadeniz (11,271 GW h), Çoruh (10,630 GW h), Seyhan (7968 GW h), Kızılırmak (6229 GW h), Yesilırmak (5308 GW h), Doğu Akdeniz (6212 GW h) and Antalya (5089 GW h) [27–30]. On

Table 4
Status of economically viable potential of hydroelectric power in Turkey.

Status of hydroelectric power	Number of hydropower plants	Total installed capacity (MW)	Average annual generation (GWh/year)	Ratio (%)
In operation	172	13,700	48,000	35
Under construction	148	8600	20,000	14
In program	1418	22,700	72,000	51
Total potential	1738	45,000	140,000	100

the other hand, approximately 50% of the additional potential of 38 TW h could be realized as small hydro power (SHP), with installed capacities of less than 10 MW. The share of SHP potential in the total, which is 3% at present, would be 14%. According to the results obtained from the pre-evaluation studies, about 15% of the increase in 126 TW h/year exploitable energy potential might be achieved by developing additional SHP potential [29–31].

6.2. Biomass and bioenergy

Half of Turkey's energy demand is covered by natural gas and oil imports. Turkey's energy demand is currently covered mainly by fossil fuels, coals, oil and natural gas and less by geothermal and hydro power plants. But Turkey as a developing country in the field of anaerobic digestion has a high potential for the production of biogas, because of their relatively high organic content of their wastes. Also animal manure and some energy crops could be a good basis for an efficient production of biogas [7,23,25].

Turkey has a great potential of biomass and bio-energy production. Biomass energy seems to have a major potential for the usage as a energy source. The total recoverable bio-energy potential in Turkey was estimated to be around 36,92 Mtoe (million tons of oil equivalent), based on the recoverable energy potential from agricultural residues, livestock farming wastes, forestry and wood processing residues and municipal wastes in 2003 [5,6]. On the other hand, the share of renewable energy sources to primary consumption is estimated to be 15% in 2008 [18]. This share has not actually changed since 2006. Additionally, the contribution of energy production share of animal wastes and plant residues to primary energy consumption in Turkey ranged from 1.2% in 2006 to 1.0% in 2008 as well. Table 6 shows production of bioenergy resources in Turkey.

In 2008, the share in electricity production from biogas to the total electricity generation was reported to be less than 0.2%, while for 2010, this share is forecasted to be 0.25%. It seems that, despite Turkey has a great potential of biomass to produce renewable energy and the law on utilization of renewable energy resources for the purpose of generating electrical energy has been brought into action in 2005 (Law No: 5346), the share of renewable energy in energy production is still low. Biogas production potential in Turkey was estimated to be around 1.5–2 Mtoe. However, since the share of renewable energy in energy production is so low, the possible contribution of biogas to this share can also be ignored. Actually, preliminary research activities using pilot-scale plants were initiated almost three decades ago by the General Directorate of Rural Services. These preliminary investigations covered production of biogas only from animal manure. However, these activities were somehow terminated in 1987. Besides, no research activity was encountered on production of biogas from agricultural residues and/or energy crops.

6.3. Geothermal energy

It is expected that the worldwide use of fossil fuels is going to decline in this century, and that geothermal energy will contribute in the replacement of those fossil fuels. Even now, the recent rise of oil and gas prices has made the development of the geothermal resources of Turkey more feasible [33–35].

In the recent years, among the renewable energy alternatives, geothermal energy in world and our country has become very attractive. The reason for this interest is features of geothermal energy in direct and indirect use. It is unfortunate that geothermal energy in direct use can only be utilized locally. But, firing fossil fuels at 1500 °C, and using the generated heat at only 50–60 °C is obviously a thermodynamic waste. Therefore, utilization of low grade geothermal energy resources fills an important gap in this area. On the other hand, although indirect use of geothermal energy with relatively low temperatures seems inefficient with respect to fossil fuel fired energy sources, it has an advantage of base-load power generation with respect to other renewable such as hydropower, biomass, wind and solar energy.

Geological studies indicate that the most important geothermal systems of Turkey are located in the major grabens of the Menderes Metamorphic Massif, while those that are associated with local volcanism are more common in the central and eastern parts of the country (Fig. 4) [35]. On the other hand, geothermal

Table 5
Renewable energy supply in Turkey.

Renewable energy sources	1990	1995	2000	2002	2007
Primary energy supply					
Hydropower (ktoe)	1991	3057	2656	2897	3442
Geothermal, solar and wind (ktoe)	461	654	978	1142	1374
Biomass and waste (ktoe)	7208	7068	6457	5974	5456
Renewable energy production (ktoe)	9660	10,779	10,091	10,013	10,272
Share of total domestic production (%)	38	40	38	40	41
Share of TPES (%)	18	17	12	13	14
Generation					
Hydropower (GWh)	23,148	35,541	30,879	33,684	35,624
Geothermal, solar and wind (GWh)	80	86	109	153	155
Renewable energy generation (GWh)	23,228	35,627	30,988	33,837	47,639
Share of total generation (%)	40	41	25	26	26
Total final consumption					
Geothermal, solar and wind (ktoe)	392	580	910	1048	1148
Biomass and waste (ktoe)	7208	7068	6457	5974	5865
Renewable total consumption (ktoe)	7600	7648	7367	7022	7134
Share of total final consumption (%)	18	15	12	12	12

Table 6
Production of bioenergy resources in Turkey.

Crop/animal	Residue	Theoretical production (tons/year)	Actual production (tons/year)	Available residue manure (tons/year)
Crop residues				
Wheat	Straw	29,270,775	23,439,910	3,520,384
Barley	Straw	9,986,879	8,954,014	1,342,460
Rye	Straw	420,214	365,08	56,712
Oats	Straw	421,658	322,238	48,216
Maize	Stalk	5,924,860	4,964,254	2,984,164
	Cob	598,574	1,908,324	1,146,394
Rice	Straw	584,545	209,544	126,716
	Husk	88,530	78,064	62,214
Tobacco	Stalk	384,762	362,643	248,685
Cotton	Stalk	6,320,186	2,534,286	1,543,24
	Ginning	484,586	424,43	435,686
Sunflower	Stalk	2,354,687	2,260,321	1,356,643
Groundnut	Shell	28,213	28,424	23,687
Soybean	Straw	62,468	21,896	13,225
Fruit and fruit tree residues				
Apricots	Shell		156,687	
	Tree pruning	1,336,646	87,212	70,242
Olive	Cake	674,686	638,926	596,876
	Tree pruning		424,464	226,432
Walnut	Shell	174,634	76,864	61,246
Hazelnut	Shell	698,246	562,642	453,224
	Tree pruning		2,065,462	1,642,245
	Tree pruning	234,742	86,642	69,664
Orange	Tree pruning	3,420,460	236,489	189,984
Mandarin	Tree pruning	978,970	996,876	82,364
Animal wastes, available dry manure and biogas				
Cow	Waste	15,864,056	10,024,123	10,024,172
Sheep	Waste	5,865,784	736,465	736,465
Poultry	Waste	1,875,543	1,864,768	1,864,768

exploration in Turkey started in the early 1960s. At first, the work was focused on high enthalpy fields for potential power production; Kızıldere was discovered in 1968. The Balçova and Seferihisar, two medium-temperature geothermal fields, were found and studied in the 1960s and 1970s, respectively. A second high-enthalpy system, Germencik, and various other medium-enthalpy fields, such as Salavatli-Sultanhisar and Simav, were discovered in the 1980s. Turkey's low- and medium temperature resources have yet to be thoroughly explored and evaluated. With proper exploration methods and investments, some might be shown to contain higher-enthalpy fluids; geochemical data seem to support such a hypothesis [35].

Turkey is one of the countries with significant potential in geothermal energy (at present seventh in the world) and there may exist about 2000 MW_e of geothermal energy usable for electrical power generation in high enthalpy zones. Turkey's total geothermal heating capacity is about 31,500 MW_{th}. At present, heating capacity in the country runs at 1220 MW_{th} equivalent to 147,000 households. These numbers can be heightened some seven-fold to 6880 MW_{th} equal to 585,000 households through a proven and exhaustible potential in 2010. Turkey must target 1.2 million house holds equivalent 7700 MW_{th} in 2020 [33–35].

6.4. Solar energy

The yearly average solar radiation is 3.6 kW h/m^2-day and the total yearly radiation period is approximately 2640 h, which is sufficient to provide adequate energy for solar thermal applications. In spite of this high potential, solar energy is not now widely used, except for flat-plate solar collectors. They are only used for domestic hot water production, mostly in the sunny coastal regions [7]. In 2006, country has about total 7.0 million m^2 solar collectors and it is predicted that total energy production is about 0.390 Mtoe in 2006. Although solar energy is the most important renewable

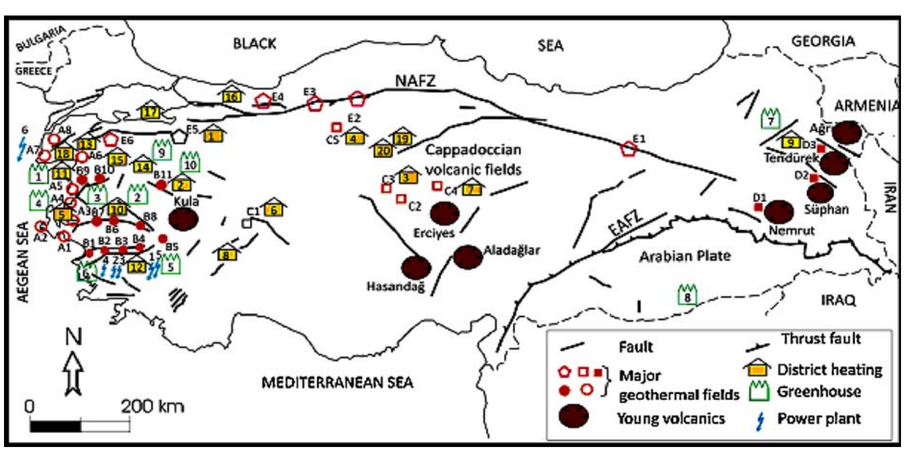

Fig. 4. Locations of major geothermal fields, district heating and greenhouse installations in Turkey.

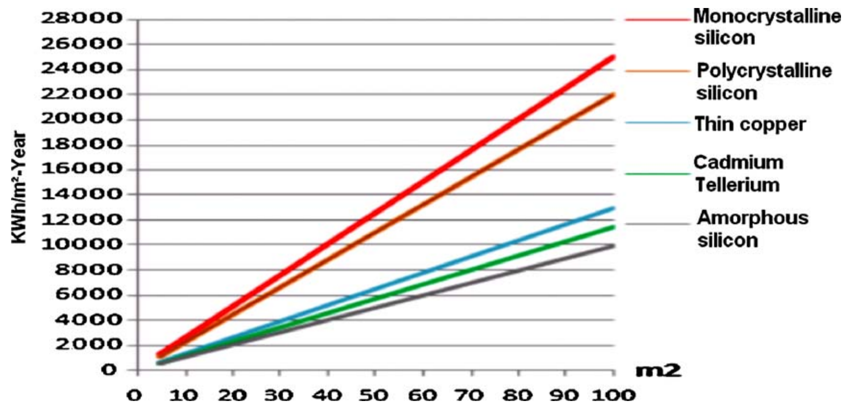

Fig. 5. The amount of energy can be produced in Turkey depending on the PV type and area (kW h/Year).

energy source it has not yet become widely commercial even in nations with high solar potential such as Turkey [23]. The energy consumption for heating and cooling of buildings in Turkey was about 23 Mtoe for the year 2006 [18]. The average household in Turkey needs more that 60% of its total energy consumption for space heating. The cooling demand in buildings increased rapidly in south region of the country at the summer season. The reason, beside general climatic and architectural boundary conditions, is an increase in the internal cooling load and higher comfort requirements. These aspects show the huge potential in this field for the implementation of advanced thermal energy storage technologies in Turkey [5–7].

The photovoltaic sector in Turkey is still fairly small, providing work for only a small number of employees. The main actors consist of several companies and a number of research institutes. There are approximately 30 companies which are operating in Turkey's PV sector. The main business types are importer, wholesale supplier, system integrator and retail sales. The companies serve in the installation, engineering and project development sectors. PV modules, battery charge controllers and inverters are mainly imported. Batteries, solar lighting systems, etc., may be supplied by the domestic market. Some of the domestic products are exported. There is not any cell production factory in Turkey [23].

The potential of Turkey as a photovoltaic market is very large, since the country abounds in solar radiation and large areas of available land for solar farms. At present, Turkey does not have any reasonable legal structure which enables the production of more PV energy and the selling of excess energy to the grid. Therefore, the most PV applications are used for stand-alone power systems. The Turkish government has to arrange the legal structure according to the PV grid-connected power systems and to finance a part of the cost. Turkey needs feed-in tariffs in the renewable energy field in order to meet European standards; as Turkey is seeking full membership in the European Union. Photovoltaic power systems should be included in the new energy programmes in Turkey [6,7].

The energy policy objectives of Turkey essentially require diversifying the energy sources, to use domestic energy resources, to increase efficiency in electricity generation and consumption and to create an environment-friendly power system. It is clear that all of these objectives include increasing the share of renewable energy sources in total electricity generation [23]. Although the Turkish government and citizens have been familiar with wind energy and accepted it as renewable energy technologies in recent years, most of them do not have enough knowledge about solar electricity potentials as alternative energy sources. Most of the Turkish people believe that solar energy that can only be used for water heating. To improve a level of understanding and acceptance of PV systems, first, the production of PV panels and the usage of the PV power systems should be promoted for low cost systems [7].

Photovoltaic (PV), is a method of obtaining electricity from the sun through silicon crystals. Crystalline solar cell layer in the bottom portion covered with one of P-type material (e.g. Aluminum, Gallium, Indium) to create green spaces. N-type top layer, covered with chemicals such as arsenic, phosphorus or antimony which create traveler electrons. The light falling on the electrons stimulate them through the lower layers (P region). In the solar cell, these electrons makes short-circuit in the ways drawn that separates two layers and circuit again through drawn road towards the entire N region and thereby generate electricity. With today's technology, depending on the used material on PV, approximately 15% of the total potential of the sun can be converted into electrical energy. Depending on the PV type and area, the amount of energy can be produced in Turkey shown in Fig. 5 [36].

6.5. Wind power

Surrounded by the Black Sea to the north, the Marmara and the Aegean Sea to the west and the Mediterranean Sea to the south, Turkey has huge potential for wind power generation. A study carried out in 2002 concluded that Turkey has a theoretical wind energy potential of nearly 90,000 MW [24]. So far only about 1000 MW capacity wind farms are in operation in Turkey, generating less than 0.5% of total electricity consumed. There are a number of cities in Turkey with relatively high wind speeds [33]. These have been classified into six wind regions, with a low of about 3.5 m/s and a high of 5 m/s at 10 m altitude, corresponding to a theoretical power production between 1000 and 3000 kW h/(m^2 yr). The most attractive sites are the Marmara Sea region, Mediterranean Coast, Agean Sea Coast, and the Anatolia inland. Turkey's first wind farm was commissioned in 1998, and has a capacity of 1.5 MW [37]. Capacity is likely to grow rapidly, as plans have been submitted for just under a further 600 MW of independent facilities. At start 2009, total installed wind energy capacity of Turkey is only 800 MW (Fig. 6). Electrical power resources survey and development administration (EIE) carries out wind measurements at various locations to evaluate wind energy potential over the country, and have started to compile a wing energy atlas [23].

Turkey, in contrast, relies heavily on imported energy. Only around 30% of the total energy demand is met by domestic sources. The European Wind Energy Association has estimated that Turkey could meet 20% of its electricity demand from wind power with a target capacity of 20,000 MW, even assuming an average 8% annual growth in power consumption. On the other hand, Turkey has plenty of great natural resources. Geographical location of Turkey is also a great advantage, especially its distance to industry demanding countries, European Union, Arabic states. In addition to that, climate is a varying factor depending on the landscape. Three sides of Turkey are surrounded by Mediterranean, Black and Aegean sea

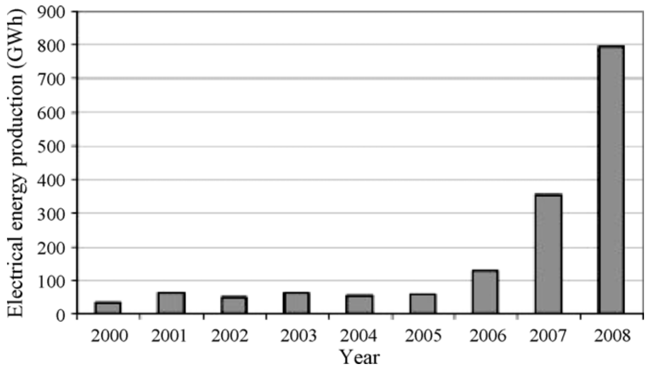

Fig. 6. Electricity production from wind energy in Turkey.

with the warm and nice weather and good amount of stable wind speeds [7].

It is shown that Turkey has plenty of renewable energy resources which are still not utilized. This paper proves that wind energy is one of those alternative renewable energy resources which help Turkish economy and development in the following years. Since wind energy is not a stable electricity source, it requires other sources of electricity production investments to different energy resources. In addition to that, the demand of Turkish Republic is much more than the amount that can be produced by wind energy. On the other hand, it is a free energy resource once all the investments are completed. Price of wind does not fluctuate and by the technological advancements in wind power engineering, repair costs, and efficiency levels and it is a great way of producing energy. As a result, it was possible to produce annual energy of 22,807 GW/year from a total wind power plant area of 628.35 km^2 which corresponds to a 35.26 GW/year per 1 km^2. Considering the fact that it is possible to produce such energy for at least 30–40 years with today's technological achievements, it is certain that wind power plants pay back every penny that is spent to build them [4–7].

7. Climate change in Turkey

Turkey is a rapidly growing country whose income level is moving towards that of the rest of the OECD area [38]. This catch-up process has been associated with a rapid growth of greenhouse gas emissions. Nonetheless, carbon emissions from any country contribute equally to the pressure on the global climate. Consequently, the major issue facing policy makers is how to contribute to reducing the burden on global resources at a low cost and without jeopardizing the rapid growth of the economy [4].

7.1. Emissions

Turkey has achieved decoupling of SO*x*, NO*x* and CO emissions from economic growth. In 2005, estimated SO_2 emissions are 1.9 million tons, increased by 6% between 1998 and 2005, while GDP and fuel consumption increased by 26 and 23%, respectively. SO*x* emission intensity (per unit of GDP) fell by 16% between 1998 and 2005. However, SO*x* emission intensity is still over three times higher than the OECD average. Major contributors to SO*x* emissions continues to be power plants (66.3%) and industrial combustion (26.1%) [38–40].

NO*x* emissions, estimated at 1.1 million tons in 2005, had increased by 17% since 1998 [38]. NO*x* emission intensity (per unit of GDP) decreased between 1998 and 2005 from 2.1 to 1.9 kg/USD 1000. However, NO*x* emission intensity still exceeded the OECD average by more than 50%. The major contributor to NO*x* emissions continued to be mobile sources. Their share in total emissions increased by 5% compared with 1998. Power stations and industrial combustion accounted for 16.9 and 18.8%, respectively (Table 7) [7,38].

Table 7
Air pollutant emissions by source x (1000 tons).

		SO_2	NO*x*	VOC	CO
Power stations	1998	1151	187	7	15
	2005	1285	183	8	23
Industrial combustion	1998	475	169	3	64
	2005	507	203	4	78
Non-industrial combustion	1998	95	191	196	1779
	2005	76	208	174	1462
Industrial processes	1998	49	22	44	17
	2005	49	18	49	7
Mobile sources	1998	63	342	88	2 791
	2005	22	456	126	474
Total	1998	1832	922	547	5167
	2005	1939	1080	554	3604

Carbon monoxide emissions amounted to 3.6 million tons in 2005, a 30% decrease since 1998 and mostly come from non-industrial (41%) and mobile (41%) sources (Table 7). Since 1998, the contribution from non-industrial fixed sources has increased while that from mobile sources has decreased by 13%. On the other hand, volatile organic compound (VOC) emissions have increased slightly. Total emissions were estimated at 554,400 tons in 2004, with non-industrial fixed sources contributing 31.5%, mobile sources 22.7% and solvents 28.4% of total VOC emissions [40].

Between 1990 and 2005 total greenhouse gas (GHG) emissions increased by 84% from 170 Tg/CO_2 eq in 1990 to 312.4 Tg/CO_2 eq in 2005 (Table 8), in line with GDP growth [14]. The energy sector accounted for 77.3% of the total in 2005. The other contributing sectors are the waste sector (9.5%), industrial processes (8.1%) and agriculture (5.1%). On the other hand, CO_2 emissions account for 82.1% and CH_4 emissions for 15.8% of total GHG emissions. Most (92%) of total CO_2 emissions are from fossil fuel combustion. The energy sector was responsible for the highest emission increase. Fig. 7 shows development of cumulative GHG emissions of Turkey by years [40].

7.2. Air quality

Trends in reducing annual average concentrations of SO_2 and particulate matter (PM) in cities showed overall progress between 2002 and 2008. In cities such as Ankara, Gaziantep, Izmit, Samsun, Sivas and Diyarbakir pollutant concentrations decreased, particularly during winter seasons, in some cities from levels over 260 μg/m^3. This progress reflects major changes in energy supply for domestic heating, with (i) natural gas substituting for coal in a number of cities and (ii) prohibition of the use of high-sulphur coal in 2005 [38].

However, in cities where industry has continued to expand, SO_2 and PM concentrations have not decreased. Average winter

Table 8
Greenhouse gas emissions from energy sector (million tons CO_2 eq).

Years	CO_2	CH_4	N_2O	Total
1990	139.6	29.2	1.3	170.1
1992	152.9	36.7	4.0	193.6
1994	159.1	39.2	2.2	200.5
1996	190.7	45.0	6.1	242.1
1998	202.7	47.7	5.6	256.6
2000	223.8	49.3	5.8	280.0
2002	216.4	46.9	5.4	270.6
2004	241.9	46.3	5.5	296.6
2006	256.3	49.4	3.4	312.4
2008	277.7	50.2	3.8	331.7

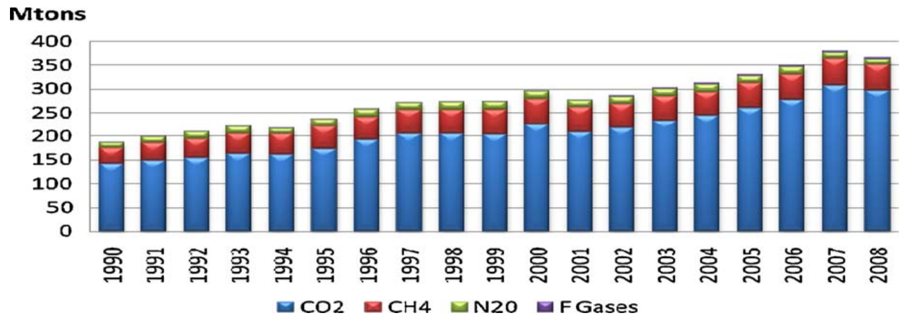

Fig. 7. Development of cumulative GHG emissions of Turkey by years.

concentrations have exceeded total limit value (TLV), and average concentrations of SO_2 and PM_{10} have remained above the World Health Organization (WHO) guideline of, respectively, 20 and 50 μg/m^3. For example, in Denizli, Kütahya, Karabük and Van, the PM_{10} concentrations reached over 130 μg/m^3 in 2007; in Kayseri, PM concentrations in the 2007/2008 winter season reached 125 μg/m^3 and SO_2 concentrations 58 μg/m^3 [7,38].

Only SO_2 and PM concentrations in ambient air have been monitored on a regular basis across the country. In certain cities other pollutants have also been monitored: in Istanbul NO*x*, CO, O_3 and HC are monitored by the municipality. A draft 2006 Regulation on Air Quality Evaluation and Management aimed to expand air quality monitoring to include 13 additional pollutants on a regular basis, in line with Turkey's commitment to transpose the EU Air Quality Framework Directive and its sister Directives [38–40].

7.3. Regulatory instruments

The regulatory framework for managing emissions from stationary sources has improved during the review period. The 2005 Regulation on Control of Air Pollution Resulting from Heating introduced new emission standards for burning facilities and required emission certificates before facility operations could begin. It also prohibited the marketing and use of coal not in compliance with quality standards. This regulation contributed to switching from coal to natural gas for heating purposes. Coal consumption in Istanbul was expected to be 1.5–2.0 million tons in the winter of 2007–2008, down from 8 to 10 million tons in earlier years.

Installations emitting air pollutants continue to be subject to two categories of permitting procedures, with a distinction between large installations. However, emissions from waste incinerators and co-incinerators are regulated mainly by waste legislation. The creation of a Turkish IPPC Centre is envisaged with information, or both information and executive, responsibilities for integrated permitting matters. The introduction of these new permitting procedures would parallel the introduction of new limit values and standards required by the transposition of EU legislation [7].

In 2007 amendments to the 1983 Law on Environment introduced provisions for tougher penalties for non-compliance with permitting procedures. For example, an administrative fine of US$18,000 was introduced for: operation of installations without a permit; continuing operation in spite of permit cancellation; performing changes on a facility without prior approval by competent authorities; not carrying out changes requested by authorities as a result of inspections [7].

Regulations on fuel quality have also been revised, in line with the EU Quality of Petrol and Diesel Fuels Directive. The use of leaded gasoline was totally banned in 2004. The Ministry of Industry and Trade employs 620 inspectors, 600 of who work in Provincial Directorates located in 81 cities and perform market surveillance activities. In 2007, the sulphur content of diesel oil was restricted to 50 mg/kg, which is 80 times lower than before. There are plans to further restrict the levels to 10 mg/kg in 2009. Sulphur content standards for unleaded gasoline are lowered to the same levels, in line with the Directive regulating the sulphur content of liquid fuels. The date of the full transposition remains set for 2010 [40].

7.4. Economic instruments

Currently, no environmental charges or taxes for managing air pollution are applied directly. Previous funding arrangements, with part of the revenue from motor vehicle inspection fees, vehicle sales and fees on airplane tickets going to the Environmental Pollution Prevention Fund, were discontinued with the Fund's elimination in 2001.

7.4.1. Environmentally related taxes

Environmentally related taxes include taxes on fuels and on vehicles. Road fuel prices in Turkey are among the highest in OECD countries. A special consumption tax on gasoline and diesel fuels was introduced in 2002 and its increase over the last five years is associated with a decrease in the use of motor fuels per unit of GDP. Given that many low-income households in Turkey do not own a car, this reform has touched middle-income and higher-income households. Since the tax rate for diesel fuel with sulphur content below 0.05% (1.0 Turkish liras/litre) is higher than for fuel with a higher sulphur content (between 0.05 and 0.20%), the wrong incentive is given from an environmental perspective [38].

The annual tax on motor vehicles also has environmental ramifications. Its rates increase with cylinder volume. As vehicles with larger cylinder volumes emit more pollutants, this provides incentives to purchase smaller vehicles. However, the tax decreases with the vehicle's age, which is inconsistent with pollution reduction objectives. The replacement of older vehicles in the fleet has been encouraged by separate economic incentives. On the other hand, preferential tax rates apply to other fuels, such as LPG and biodiesel. For example, the LPG tax rate is EUR 0.30/litre compared to EUR 0.78/litre for low-octane unleaded gasoline. This differentiation provides incentives to use LPG. When gasoline or diesel is mixed with bio-fuels (ethanol and bio-diesel) manufactured from domestic agricultural products, a lower tax rate is applied according to the mixing ratio.

7.4.2. Energy prices

Retail electricity prices are relatively high in Turkey, at approximately USD 0.163/kW h for households and USD 0.1/kW h for industrial consumers (Table 9) [38]. Turkey currently has implicit cross-subsidies between regions and for certain subcategories of consumers. The government is considering a transition period, with a tariff equalisation method, to reduce cross-subsidies and progressively introduce cost-effective tariffs in the medium term.

Table 9
Energy prices in selected OECD countries in 2007.

Countries	Electricity		Oil		Natural gas	
	Industry (US$/kW h)	Households (US$/kW h)	Industry (US$/ton)	Households (US$/ton)	Industry (US$/$10^7$ kcal)	Households (US$/$10^7$ kcal)
Turkey	0.109	0.163	786.0	2 278	440.8	696.1
Mexico	0.102	0.135	259.3	n.a	347.1	917.0
Korea	0.069	0.129	551.9	1 269.1	551.1	902.5
France	0.056	0.130	407.9	728.7	414.1	646.5
Germany	0.094	0.200	n.a	677.5	n.a	n.a
Poland	0.082	0.216	354.1	1 281.1	375.1	983.1
Portugal	0.128	0.222	n.a	1 032.7	428.8	1 119.3
OECD Europe	0.106	0.169	n.a	755.2	n.a	n.a
TUR price/OECD Europe (%)	94	104	n.a	n.a	n.a	n.a

Differences in energy prices are mainly due to tax differentiation by fuel types: the special consumption tax on natural gas is much lower than on fuel oils. However, no special consumption tax is applied to coal.

8. Integration of air quality concerns into energy policy

The basic principle of Turkish energy policy, as set out in the 9th National Development Plan (2007–2013), was to ensure sufficient energy supply to meet the increasing demand, at the lowest cost possible. The Ninth Development plan also introduced provisions for minimising negative environmental impacts, improving energy efficiency and increasing the share of renewable energy in energy consumption [19].

8.1. Reducing pollution from energy production

The government further reformed the regulatory framework to reduce pollution from energy production. In 2006, the new Regulation on Control of Air Pollution from Industrial Plants set standards for emissions of NOx, SO_2, CO and PM from combustion plants. PM and CO standards were lowered for both solid and liquid fuel-fired power plants. PM standards were tightened from 150 to 100 mg/m^3 for solid fuel-fired power plants and CO standards were lowered from 250 to 200 mg/m^3 (for solid fuel-fired plants) and from 175 to 150 mg/m^3 (for liquid fuel-fired plants) [7,40].

Some investments have already been made, especially to address the environmental impacts of the high sulphur content of domestic lignite. New lignitefired power plants have been equipped with flue gas desulphurisation (FGD) technology to comply with regulations. Six of eleven pre-1986 lignite-fired plants have been retrofitted with electrostatic precipitators (ESP) to reduce particulate emissions. However, not all electrostatic precipitators are working at maximum efficiency. Construction of one power plant based on circulating fluidised bed technology has recently been completed [18,20]. This first application of advanced coal technology in Turkey, designed to use low-quality lignite with high sulphur content, was followed by other plants. Studies on compliance with the EU LCP Directive indicate that an investment of over USD 1 billion would be needed to retrofit installed FGD and ESP facilities and to adopt advanced coal technologies [38–40].

8.2. Improving energy efficiency

Energy intensity decreased by 8% between 1990 and 2005 and is below the OECD average. Its improvement through improved sectoral energy efficiencies is an important objective of Turkey, which should bring multiple benefits: economic benefits, environmental benefits and related health benefits. Official studies have demonstrated that Turkey has large energy conservation potential (25–30%) [23]. Energy efficiency policies have been implemented in the industrial, residential and services sectors. General investment support programmes also have an indirect positive impact on energy efficiency. There are no direct tax incentives to encourage end-use energy efficiency, nor is there any other kind of direct financial incentives. On the other hand, the National Energy Conservation Centre (EIE/NECC) has provided training to consumers on energy conservation measures, conducted energy audits in industry, maintained energy consumption statistics for the industrial sector and public buildings, and co-ordinated dialogue and co-operation with the relevant institutions. In 2004, the Energy Efficiency Strategy was adopted to support, in a more comprehensive way, energy efficiency in the final energy consumption sectors and more actively engage ministries and stakeholders in applying energy efficiency measures [23].

8.3. Promoting renewable energy

In Turkey, renewables represent about 12% of total primary energy supply (TPES). More than half of the renewables used in Turkey are combustible fuels and waste, the rest being mainly hydro, solar and geothermal. Turkey is richly endowed with hydropower, wind and geothermal resources. Sectoral studies have indicated that small-scale hydropower (less than 20 MW) is underdeveloped, with 90 plants in operation compared with 350 prospective development sites and a total potential production of 33 TW h of electricity per year (about 25% of current demand). It is estimated that Turkey has the potential for up to 11,000 MW of wind power capacity (mostly along the coasts), capable of generating about 25 TW h of electricity per year [7,18,20,30]. But today (2008) the installed wind power capacity for electricity generation is very low as shown in Fig. 8.

There is also large potential for geothermal and solar thermal applications in Turkey. Solar collectors are already a significant, market-driven business. The government expects the use of renewables for electricity generation will be double between 2009 and 2020 (Fig. 9). The Geothermal Energy Law, enacted in 2007, aims to boost geothermal residential heating. The organic component of waste incineration is also considered a renewable option in the future, using appropriate technology to meet high health and environmental standards. On the other hand, commercial use of renewable energy has not developed rapidly. Financial assistance is being provided for the development of renewable energy projects. In 2004, USD 200 million was made available; by 2008, about half had already been committed to finance 19 projects with several other projects under preparation [19,38].

Source	MW
Natural Gas	16.443
Hydro (Dam)	12.682
Hydro (Run-of-River)	1.995
Lignite	8.140
Liquid Oil	1.820
Imported+Hard Coal	2.815
Wind	1.014
Geothermal	94
Renewable+Waste	88
Asphaltite	135
Total	45.226

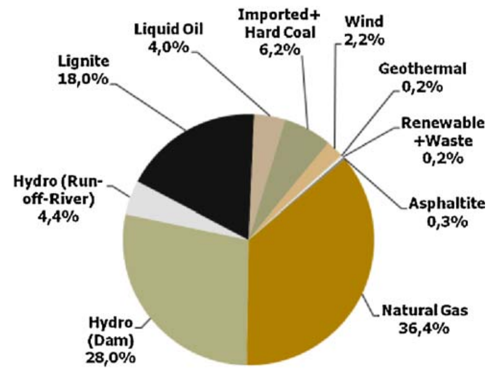

Fig. 8. Installed electricity capacity and shares by sources in Turkey (2008).

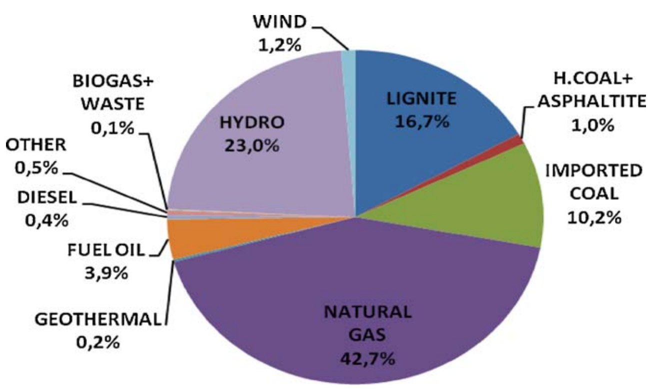

Fig. 9. Share of sources in electricity generation of Turkey in 2020.

Turkey is an energy importing nation with more than 70% of our energy requirements met by imported fuels. Air pollution is becoming a significant environmental concern in the country. In this regard, hydropower and other renewable energy sources are becoming attractive solution for clean and sustainable energy future of Turkey. Renewable energy supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources such as solar and wind. Turkey's geothermal potential ranks seventh worldwide, but only a small portion is considered to be economically feasible. Renewable energy sources exception of large hydro are widely dispersed compared with fossil fuels.

9. Conclusions

Energy access for all will require making available basic and affordable energy services using a range of energy resources and innovative conversion technologies while minimizing GHG emissions, adverse effects on human health, and other local and regional environmental impacts in the country. Wide range of energy sources and carriers that provide energy services as a sustainable manner need to offer long-term security of supply, be affordable and have minimal impact on the environment. Climate change has been identified as one of the greatest challenge by all the nations, government, business and citizens of the globe. The threats of climate change on our green planet 'Earth' demands that renewable energy share in the total energy generation and consumption should be substantially increased as a matter of urgency. Due to predominance of fossil fuels in the generation mix, there are large negative environmental externalities caused by electricity generation. So it has become imperative to develop and promote alternative energy sources that can lead to sustainability of energy and environment system. Renewable electricity has become synonymous with CO_2 reduction.

Present communication provides a brief description about such alternative and sustained energy sources, i.e., renewable energy resources, their potential and achievements in Turkey. Also role as important tool for climate change mitigation. Many renewable energy (RE) technologies are currently commercially available or just starting to be applied on a more or less commercial base, e.g. in demonstration projects followed by diffusion to the market. Other RE technologies are still less mature and deserve perhaps another 5–10 years before commercialisation.

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